ASSESSMENT OF LOCAL MATERIAL FOR DRILLING FLUID FORMULATION

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Assessment of Local Material for Drilling Fluid Formulation

By

Lenis Chan Chia Yam

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JUNE 2010

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CERTIFICATION OF APPROVAL

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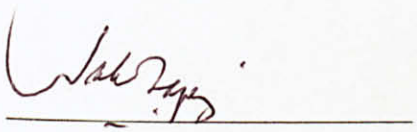
Approved by,



Dr. Nasiman Sapari
Project Supervisor

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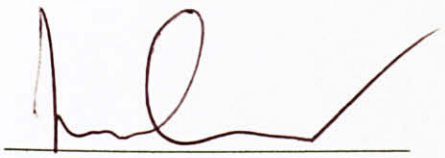
JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



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ABSTRACT

Drilling fluid is an essential element in oilwell drilling and completion processes. It fulfills several fundamental requirements which facilitate safe and satisfactory drilling activities such as controlling high pressure zones and allowing the removal of cuttings to the surface. Drilling fluid can be classified into three basic types, specifically water based mud, oil based mud and gas. The main component in water based mud is clay (mostly bentonite) which contains montmorillonite as its major component. As bentonite is usually imported into our country, it increases the overall cost of oilwell drilling and completions. Thus, the characterization and synthesis of local bentonite clay is essential in the reduction of cost for upstream oil and gas activities. The objectives of this project are to characterize clay samples from Grik, Perak in terms of mineral composition and physical/ chemical properties. The synthesis of clay samples and formulation of drilling fluid will be looked into subsequently. The scope of study of this project is the formulation of water based drilling fluid utilizing clay samples from Grik, Perak. The specification target for purified clay samples is standard Wyoming Bentonite while for water based drilling fluid is American Petroleum Institute 13(A). The review of previous researches shows that this topic has been researched into in the past both locally and internationally. Local bentonite samples from Malaysia (Sabah), Saudi Arabia and India have been utilized for improvement processes with techniques such as Wet Treatment, Electrolysis Treatment, Oxalic Acid Treatment and Sedimentation Technique used. For this project's methodology, the process of characterization and purification occurred after obtaining the samples. Subsequently, the drilling fluid was formulated, tested and additives added. The Atterberg's Limit Test indicates that the samples obtained are low plasticity clay by nature while XRF and XRD results alongside research from Jabatan Mineral & Geosains Perak indicates that the specimen is a potassium-rich tuff containing abundant potassic feldspar and is highly probable to be illite. Bentonite augmentation in the form of Sodium Hydroxide (NaOH) was conducted but does not meet American Petroleum Institute 13[A] specifications. As a conclusion from the assessment of Grik clay, the sample was found to be unsuitable for usage as drilling fluid.

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I would like to take the opportunity to thank my supervisor, Dr. Nasiman Sapari for guiding and giving me his entire support throughout the entire process of completing this Final Year Project. I would also like to thank Dr. Sonny Irawan for his technical expertise in the project. I would have not been able to fully research into this particular matter if it was not for his knowledge and understanding in this particular field.Other than that, I would like to thank the lab technicians from the Civil Engineering Mechanical and Geoscience & Petroleum Engineering Department for obtaining the samples, aiding and guiding me while I conducted the experiments. I would also wish to express my gratitude to the personnels from Jabatan Mineral & Geosains Perak for allowing me to do the research required into the geological setup of Grik, Perak. Lastly, I would like to thank my family and friends for giving me the encouragement, motivation and moral support needed to complete my Final Year Project.

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CHAPTER 1

INTRODUCTION

The dissertation presents the research and experimental progress for the Final Year Project Topic entitled Assessment of Local Material for Drilling Fluid Formulation. The introduction provides a description of the background, problem statement, objectives and scope of study for this report.

1.1 Background

1.1.1 Drilling Fluid

Drilling fluid is an essential element in the exploration and production stages of any oil well. Drilling fluid includes all types of materials used to aid in the production and removal of cuttings from a borehole in the earth (Gray & Darley, 1981, p.1). Al-Homadhi (2007) stated that the main functions of a drilling fluid are to:

- Remove cuttings from the wellbore and separate these cuttings at the surface
- Control high pressure zones.
- Cool, clean and lubricate the Bottom Hole Assembly (BHA) drilling equipments.
- Ensures the stability of borehole wall through the formation of filter cake.
- Supports the weight of drill string and casing

Gray & Darley (1981) explains that drilling fluids can be categorized on the basis of a primary component. These components are water, oil and gas. These fluids are usually present simultaneously and each component contributes to the properties of the drilling fluid (p.2). Drilling fluid selection require consideration of numerous factors. Bieler (1990) stated that the selection factors are:

1. Safety Issues (Well Control, Gas Hydrates, H_2S)

   -The fluid must be able to bear the mud weight required to control the well. The rate and ease with which a mud will accept weighting materials (Barite, Galena and Siderite are also important considerations especially in the event of a pressure surge in the well.

   -Gas hydrates can impede mechanically well-control operations in deepwater drilling. Salt mud is widely used for such operations as its' high salinity prevents the formation of hydrates

   - The existence of H_2S is a major hazard in any oilwell facilities. Lime and oil mud are usually the fluid of choice for drilling H_2S-bearing zones.

2. Evaporite Zones

   -Water based drilling fluid causes leaching in evaporite zones unless the fluid has been pre-saturated with evaporite before the commencement of drilling. Gypsum mud, salt mud or oil mud are usually the natural choices for anhydrite and thick salt evaporite zones.

3. High Temperatures and Pressures

   -Water based mud faces high temperature gelation and fluid loss control problems at downhole temperatures of 250 to 350°F. Oil mud is an economical alternative at such high temperatures and pressures.

4. Environmental Considerations

   -Environmental restrictions imposed limit the choice of drilling fluid that can be used. Certain well locations avoid the usage of oil, salt and chromium treated mud.

5. Severe Loss Zones

   - The existence of thief zones which causes losses of mud affect the type of mud used. Lost circulation materials (LCM) which are more economical in nature can be utilized if high losses zones which cause large mud volume losses are known in advance. This tends to rule out oil mud and heavily treated water based mud.

6. Shale Problems

   -Mud selection is also influenced by shale formations as shale can swell, disperse or slough into the hole which causes problems to the drilling process. Currently, a combination of potassium, polymer, lime, gypsum, salt mud and other additives are used to solve this problem

1.1.2 Clay

In this project, we will be looking into the main component of water based mud which is clay. Clay has been described as particles smaller than 2 microns that exhibits significant strength when dried and reduced strength with the addition of water (Budhu, as cited in USCS (ASTM (D2487-93), 2007, p.45). Budhu (2007) also stated that the main compositions of crystalline materials that make up clay are the minerals: kaolinite, illite, and montmorillonite. Kaolinite has one silica sheet and one alumina sheet bonded together into a layer about 0.72nm thick that is stacked repeatedly and held together by hydrogen bonds. Illite consists of a single alumina layer placed in between two silicate sheets to form a layer which is then stacked repeatedly with a thickness of 0.96nm and held together by potassium ions. Montmorillonite is the main constituent of volcanic ash weathering product called bentonite. has a similar structure to illite with the difference being that the layers are held together by weak Van Der Waals forces and exchangeable ions. Water can thus easily enter the bond and separate the layers in montmorillonite and subsequently cause swelling of the clay (p.14). The most used clay for drilling fluid formulation is bentonite clay which has a large amount of montmorillonite as its major component. The physical and chemical properties of bentonite clay and its' main component, montmorillonite will be explained in a more detailed manner in the Literature Review chapter.

1.1.3 Sample Location Information

The region where the sample was obtained for research and formulation in the Final Year Project "Local Material for Drilling Fluid Formulation" lies in the vicinity of the town of Grik in the District of Upper Perak, Perak State, in the northern middle region of Peninsula Malaysia. The Grik area is bounded on the north and south respectively by latitude lines of 5° 30' N. and 5° 15' N., and on the east and west by longitude lines of 101° 15' E. and 101° 00' E. (Jones, 1970, p.1). The position of Grik area as a whole is shown in the figure below. Accompanying geological maps that will be shown in the Literature Review section utilizes the topographical sheet shown below as a base map.

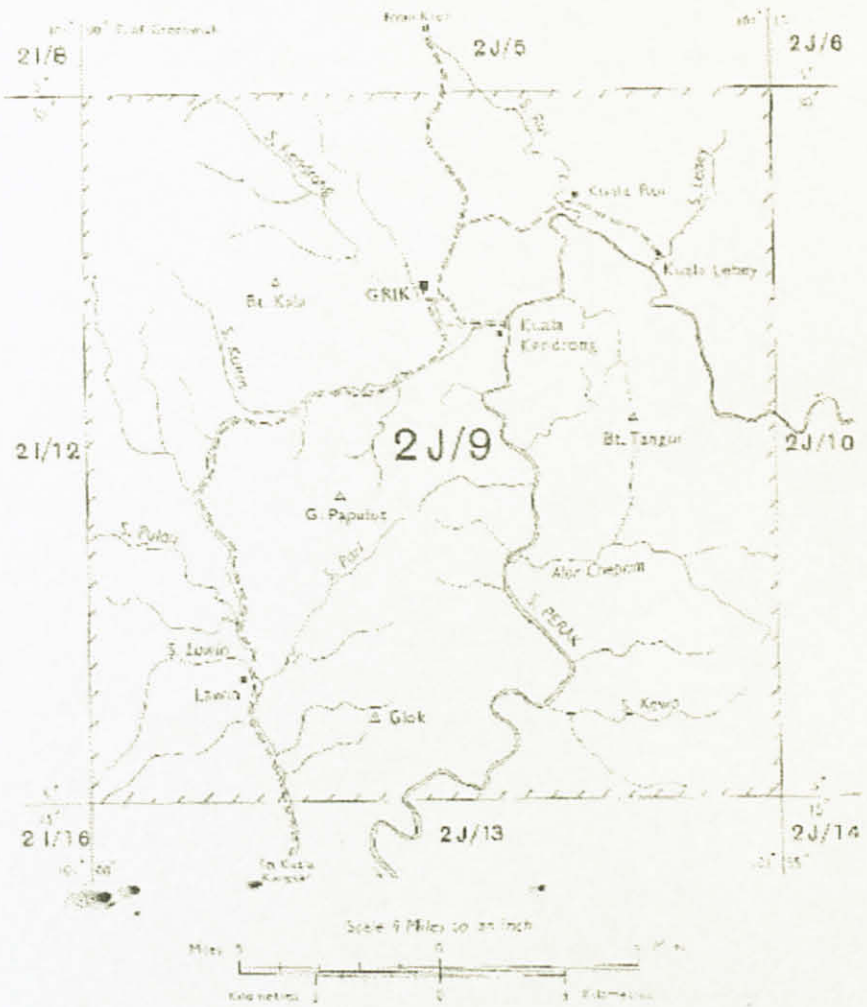

Figure 1: Grik Topographical Area (After Jones, 1970)

Jones (1970) stated that the Grik area is situated on the upper part of Sungai Perak valley and is to some extent west of the main mountain axis of Peninsula Malaysia.

Grik as a whole is not confined by any well-marked geographical features. The map shown above consist of a central tract of undulating to low-mountainous, well-forested terrain bordered by two ranges of high granite mountains, which are the Bintang Hills on the west and the Main Range on the east. Sungai Perak meanders through a northeast to south-west direction thus dividing the area into two unequal parts of which the larger section is on its north-west side (p.1).

Jones (1970) acknowledged that the Grik area conforms well to the rest of the Peninsular Malaysia in both geological and structural relationships. However, due to its relative position on the inner belt of the Mesozoic Orogen, sedimentary-pyroclastic rocks from the Paleozoic age have buckled to a greater degree than usual marginal shelf regions. The author has also concluded that the area generally suffered deformation during the late tectonic phases of the orogeny due to the zones of intense shearing effecting bedded sedimentary-pyroclastic rocks and synorogenic granite in certain places (p.25).

The entire geological setting of Grik comprises intricate sequence of sedimentary-pyroclastic layers of Lower Paleozoic age which were possibly affected by an Upper Paleozoic phase of deformation and further deformed and intruded by granite during the Mesozoic (Malayan) Orogeny. The earlier pre-granite sedimentary strata consist of thick arenaceous deposits laid down along the subsiding shelf regions of Lower Paleozoic geosyncline. This particular depositional condition was altered with the presence of deeper water geosynclinal conditions under which anoxic deposition of predominantly argillaceous character occurred. Parallel with this particular sedimentation is a period of explosive volcanic activity which appears to have occurred during the time of transition from shallow to deeper water conditions thus causing large depositions of water-laid rhyolite and rhyodacite crystal tuff. The geology and geochronology of the Grik area where the samples were exactly obtained will be discussed further in the Literature Review section.

1.2 Problem Statement

The oil and gas industry worldwide relies heavily on Wyoming bentonite as the main component in various classifications of water based mud and this trend is expected to continue as drilling activity increases worldwide. With the heavy dependence of this material in the Malaysian oil and gas industry, this causes an increase in the overall cost of oilwell drilling and completion projects locally. Thus, the large utilization and high importation cost of Wyoming bentonite has lead to an attempt to find a local substitute that will be able to fulfill general quality standards for bentonite and the formulated drilling fluid as specified by the American Petroleum Institute (API).

1.3 Objectives

The objectives of this project are to:

- Assess the suitability of local clay for drilling fluid formulation.
- Identify the properties of clay samples (mineralogy, chemical and physical properties) obtained from Grik, Perak.
- Compare the properties of clay samples with Wyoming Bentonite.
- Purify and process clay samples from impurities.
- Formulate and improve drilling fluid from clay samples and compare drilling fluid with required specifications (American Petroleum Institute).

1.4 Scope of Study

In order to ensure the feasibility of this research project within the given time frame, the boundaries of the project work is narrowed down. Among the boundaries selected are:

- Clay Sample Utilized

  -The clay samples that will undergo analysis and drilling fluid formulation are taken from Grik, Perak.

- Drilling Fluid Formulated

  -As mentioned above, there are various types of drilling fluid available in the market. In this research project, we will look into the formulation of water-based drilling fluid utilizing clay samples taken from Grik, Perak as a principal ingredient.

- Specification Target

  -The clay sample obtained and purified shall be compared against standard Wyoming Bentonite which is the highest quality clay for use in drilling fluid while the drilling fluid formulated must meet American Petroleum Institute specifications.

CHAPTER 2

LITERATURE REVIEW

The utilization of a country's local clay samples as the main material in drilling fluid has been a subject of research both in the oil and gas industry and by universities worldwide. The literature review will first and foremost give an in depth look into the area where the sample was obtained, Grik, Hulu Perak by providing required geological and geochronological information regarding the said area. Subsequently, we will be looking into the main component of clay samples that is usually used as drilling fluid, which is bentonite. The literature review will give an in depth view into the properties of bentonite followed by bentonite quality evaluation. Thereafter, we will look into methods used to increase clay quality to fit Wyoming bentonite properties and the evaluation of drilling fluid properties. Finally, the literature review will look into the methods available to improve drilling fluid performance formulated from local clay.

2.1 Geology and Geochronology of Grik

This section will look into the geology and geochronology of the specific area where the samples were obtained. A simplified sketch-map is shown in the figure below.

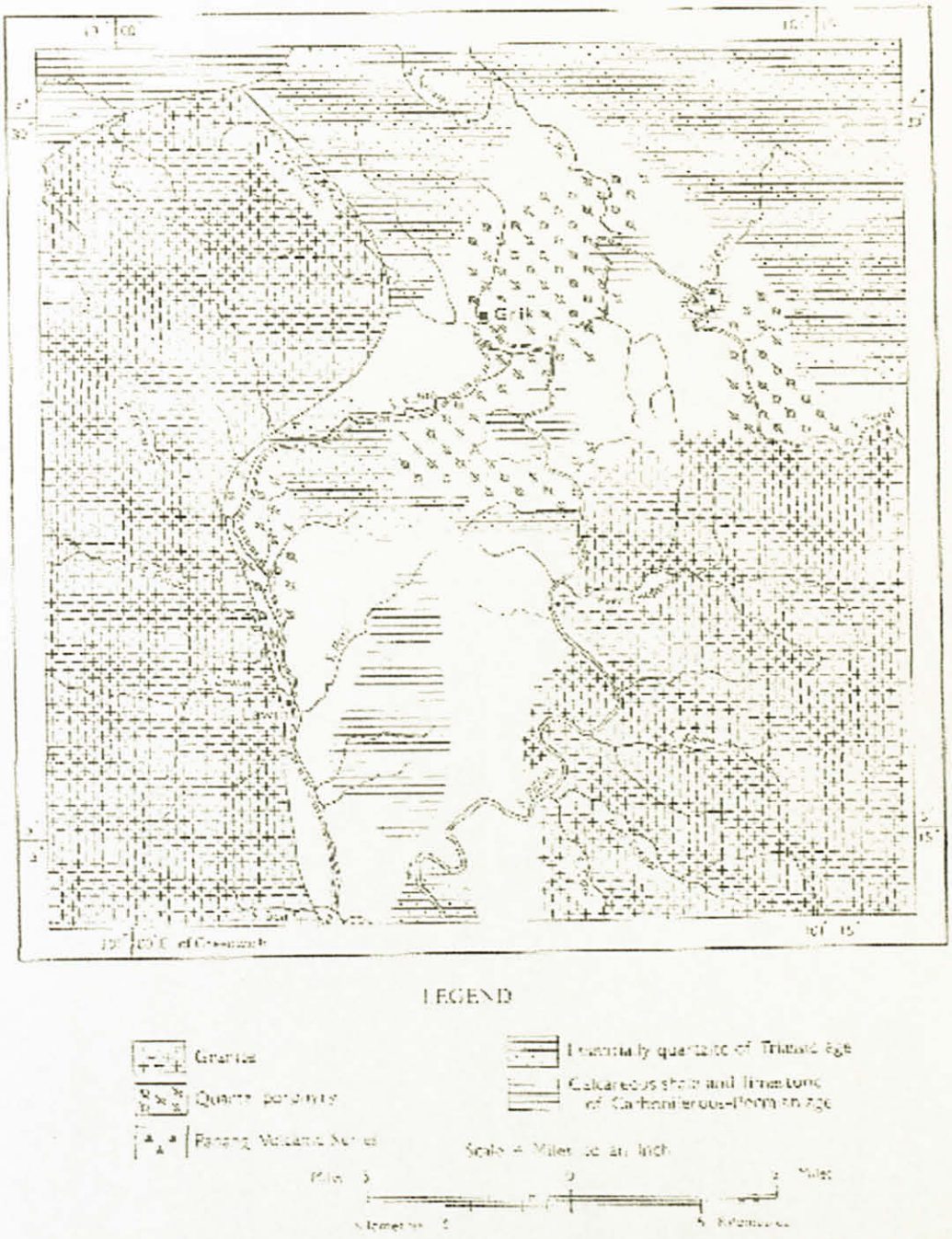

Figure 2: Simplified geological sketch-map of Grik area (After Jones, 1970).

Jones (1970) stated that the sketch-map shown above were mapped on a lithological basis but lateral correlation proved complex due to the rapid vertical facies changes and interfingering of facies. The samples were obtained from a region that has been

described by the author as to be of bedded, well-sheared and speckled rhyolitic and rhyodacitic crystal tuff and are considered to be entirely of pyroclastic origin. The tuffs have been noted by the author to be in grey to green, speckled, and bedded rocks composing of grains and crystal fragments of quartz, potassic feldspar, perthitic feldspar, and plagioclase feldspar of up to 5mms in size. It was also mentioned that these materials were set in a fine-grained matrix of quartz, mica, and chlorite alongside a large amount of volcanic dust and is now in the form of fine siliceous matter and iron oxide. The table below indicates the chemical compositions of three specimens of tuff obtained from the area.

Constituents	Percentages		
	Specimen 1	Specimen 2	Specimen 3
SiO_2	66.8	79.5	68.2
AL_2O_3	16.1	9.6	12.9
Fe_2O_3	1.89	0.96	0.92
FeO	1.82	1.35	4.01
TiO_2	0.14	0.33	0.39
MnO_2	trace	trace	0.19
P_2O_5	*0.05*	*0.06*	*0.1*
MgO	1.65	0.73	2.02
CaO	0.22	trace	4.1
Na_2O	0.21	0.14	2.29
K_2O	6.59	4.17	3.37
CO_2	0.07	0.07	0.29
H_2O-105C	0.78	0.18	0.24
H_2O+105C	3.57	1.92	1.31
Totals	99.89	99.01	100.33

Table 1: Chemical Analysis of Tuffs From The Grik Area (After Jones, 1970)

Jones (1970) stated that the first two samples were collected from a road exposure at milestone 3 on the Grik to Kuala Rui road while the third sample was obtained from Sungai Nak Sah which is about 1.2km south of Bukit Nak Sah. Specimen 1 has been defined as potassium-rich tuff containing abundant potassic feldspar and has been classified as rhyolitic. Specimen 2 mean while has been acknowledged to be tuffaceous sandy shale containing abundant detrital quartz and is believed to be obtained from a band interbedded with the pure tuff of specimen 1. Specimen 3 however has been characterized as tuff which contains high soda and lime alongside lower potash contents as compared to those found in specimen 1 (p.67).

Jones (1970) stated that the composition forms an important section of the Baling Formation and has been termed Grik Pyroclastic. Occurrences of this form of tuff are certain only in Upper Perak although possible equivalents have been recorded in Kedah and also south of Perak. The area of such pyroclastic facies have been estimated to be some 60 miles of the map sheet by the author and is concentrated in two main areas. The larger of these is centred around Grik where the sample was obtained (north half of the sheet) and the other around Lawin to the southeast. There is much interfingering of tuffs in these two areas with beds of shale, phyllite, and quartzite of the Baling Formation.

These rocks also contain variable quantities of detrital material produced by normal erosional process and on weathering, the tuff forms a sticky, gritty, light-brown to grey clay and poorly fertile soil in which quartz are abundant. The author notes that the depth of weathering is shallow due to formation of the mantle of impervious clay.

Jones (1970) stated that these volcanic rocks is considered to have been formed during mid-Paleozoic or more specifically Ordovician (488 MYA- 444MYA) period of diastrophism. This particular rock intrudes laterally and vertically into arenaceous and argillaceous facies. The volcanic fragments were laid at the same time and in close association with detrital strata of the Baling Formation. These rocks are considered to represent a time of explosive acid volcanism and ensuing marine deposition of the erupted material. Evidence also indicates that the marine deposition activity coincides with the time of change from shallow-water shelf deposition characteristic of the lower part of the Baling sequence to that of deeper water geosynclinals conditions of the upper part of the succession (p.62).

2.2 Properties of Bentonite

Bentonite $(Al_{0.2693}\ Fe^{2+}_{0.7212}\ Mg_{0.1374})\ (Si_{3.5808}\ Al_{0.4192})X_{0.5855}nH_2O$ is the most plentiful of the smectite group of clay and has generally been classified in the petroleum industry as sodium (Na) or calcium (Ca) types depending on the principal exchangeable ion (Irawan & Samsuri, 2007). Patel, Somani, Bajaj, & Jasra (2007) mentioned that bentonite clay was formed by siliceous, glass rich volcanic rocks (e.g. tuff & ash deposits) that have been altered. Patel et al. (2007) also states 'The major mineral in bentonite is montmorillonite, having hydrated sodium, calcium, magnesium and aluminum silicate'. Ran, Daemen, Schuhen & Hansen (1997) also mentioned that bentonite also contains minute quantities of feldspar, biotite, selenite and etc and has a tri-layer expanding mineral structure. Gray & Darley (1981) stated that montmorillonite swells greatly because of its expanding lattice and the increase in c-spacing depends on the exchangeable cations. Certain cations such as sodium has a swelling pressure that is strong enough to separate into smaller aggregates and even into individual unit layers. This property gives bentonite excellent adsorption abilities (pg. 146).

2.3 Bentonite Quality Evaluation

Al-Homadhi (2007) stated that the quality of bentonite can be established by four parameters:

1) Components within the clay other than montmorillonite
2) The types of counter-ions present on the montmorillonite platelets.
3) The availability of extending polymer
4) The size and charge of the montmorillonite platelets

Bol (1986) stated that the highest quality of bentonite contains only montmorillonite and will have its quality affected in the presence of other materials such as kaolinites, illites, chlorites (all clay), quartz and feldspar. The presence of counter-ions other that sodium to counter the negative charges will also reduce hydration capabilities and thus decrease the usefulness of the bentonite sample. Thickness of montmorillonite which ranges from 1 to 8 nm and surface diameter from 0.01 to 0.1μm will also affect the swelling characteristics of the bentonite sample and thus its' quality.

Previous works regarding the evaluation of bentonite clay samples is as stated below and have been separated according to the physical or chemical properties. A list of analyzed physical and chemical properties of Wyoming Bentonite as obtained from Samsuri et al (2003) is as shown in Table 2, 3 and 4. These properties of Wyoming Bentonite data will be utilized as a benchmark in the comparison of the Grik clay samples and its' refined sample and their suitability as drilling fluid material. The quality of bentonite has been shown to be evaluated according to their physical and chemical properties.

Parameter	Data
Liquid Limit (%)	583.12
Plastic Limit (%)	57.64
Plasticity Index (%)	524.48
Ignition Loss (%)	8.53
Cation Exchange Capacity (meq/100g)	79
Specific Surface Area (m^2/g)	819.62

Table 2: The physical and chemical properties of standard Wyoming Bentonite

Chemical Compund	Chemical Composition (% weight)
Fe	13.98
Na	4.13
Mg	5.15
Al	15.83
Si	57.58
K	0.51
Ca	1.88
Mn	0.94
Total	100

Table 3: The chemical composition of standard Wyoming Bentonite

Composition	Percentage
SiO_2	63.59
Al_20_3	21.43
Fe_2O_3	3.78
CaO	0.66
MgO	2.03
Na_2O	2.70
K_2O	0.31
Bound H_20	5.50
Total	100

Table 4: Oxide Composition Percentage of Standard Wyoming Bentonite

2.3.1 Physical Properties

Samsuri, Leyong, & Abdullah (2003) utilized X-Ray Diffraction (XRD) to determine the mineralogical constituents within the bentonite samples. Samsuri et al (2003) also stated that the Atterberg Limits Test, Ignition Loss (IL), Moisture Content (MC) and Moisture Adsorption (MA) were conducted so as to obtain information on the nature and quality of the physical properties of the mineral that is parallel with the requirements as stated by Al-Homadhi. The Atterberg Limits Test enables us to determine the predominant type of mineral and soil type of a sample (Budhu, 2007, pg. 49). Samsuri et al. (2003) also mentioned that Moisture Adsorption can be used to predict the mineralogical nature of clay. Bentonite that has a value of 23% and greater indicates that the sample contains a large amount of montmorillonite while values lesser than 3% indicate that the clay consists of materials such as kaolinite. A value between the range of 3% and 23% indicates the presence of montmorillonite, kaolinite and other impurities.

2.3.2 Chemical Properties

Samsuri et al (2003) stated that the chemical properties of a clay sample that were determined in the authors experiment were chemical composition, cation exchange capacity (CEC) and specific surface. Chemical compositions test enables the identification of major chemical compounds within the clay samples that will largely influence the usability of clay samples as drilling fluid such as Fe, Na, Si, Al and etc. The results from a CEC test on the other hand enable us to quantify the hydration and swelling capability of clay samples as a material in drilling mud (Irawan & Samsuri, 2007). Cation Exchange Capacity was determined by using the Methylene Blue Test while the chemical compositions test uses a specific instrument (EDAX Philip Series-40). The specific surface determination uses the Methylene Blue Spot Test.

2.4 Bentonite Quality Augmentation

Major work has been done worldwide in the field of bentonite quality augmentation to enhance the quality of bentonite in clay. The Wet Treatment and Electrolysis process as done by Samsuri et al (2003), Oxalic Acid Treatment by Irawan & Samsuri (2007) and Sedimentation Treatment by Patel et al (2007) are the methods available for increasing bentonite quality and removal of impurities.

2.4.1 Wet Treatment

Samsuri et al (2003) stated that the most common method of enriching non-sodium based bentonite to sodium based bentonite is through the wet treatment process in addition to the usage of sodium carbonate (soda ash), sodium chloride (salt), sodium bicarbonate and sodium hydroxide (caustic soda). The non-sodium based bentonite will be mixed in a solution/ high moisture condition saturated with sodium ions that will be used as an exchange medium.

2.4.2 Electrolysis Treatment

Samsuri et al (2003) conducted the electrolysis treatment with variation of electrolyte solution (sodium carbonate/Na_2CO_3) from 0.5% to 7.5%. DC power supply of 6V, 9V and 12V was used with the aluminum cathode and anode being $15cm^2$(1cm x 15cm).5 grams of bentonite were mixed with the electrolyte solution before the treatment was conducted.

Samsuri & Abdullah (2002) stated that the chemical reactions from the electrolysis treatment process are:

$$Na_2CO_3(s) \rightarrow 2NA^+(aq) + CO_3^{2-}(aq)$$

$$2H_2O(aq) \rightarrow 2H^+(aq) + 2OH^-(aq)$$

$$2OH^-(aq) + 2NA^+(aq) \rightarrow 2NAOH(aq)$$

$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2CO_3(aq) \quad +$$

$$Na_2CO_3(s) + 2H_2O(aq) \rightarrow 2NAOH(aq) + H_2CO_3(aq)$$

Following which Samsuri & Abdullah (2002) concluded that with the addition of Calcium based bentonite with other mineral content (M-X) into the solution, the

calcium based bentonite will diffuse into its separate ions and the following reaction will occur:

$$CaX \rightarrow Ca^{+} + X^{2-}$$
$$MX \rightarrow M^{+} + X^{-}$$

From the above equations, the formulation sodium based bentonite will be produced:

$$2Na^{+} + X^{2-} \rightarrow Na_2X$$

From both the wet and electrolysis treatments, it was shown that the clay samples had been successfully upgraded after wet and electrolysis treatment and that the mineral content and more specifically of sodium bentonite influences the plasticity of clay samples. The results are as shown in Appendix 1.

2.4.3 Oxalic Acid Treatment

Irawan and Samsuri (2007) considered the extraction of residual iron impurities in clay samples through the usage of oxalic acid solution. 7.1 kg/m³ of oxalic acid solution was blended with the bentonite samples for 2 hours at 80°C temperature to increase the smectite content by removing iron and impurities. The oxalic acid treatment improves the CEC and specific surface area of the bentonite samples but does not meet reference bentonite requirements as shown in Appendix 2.

2.4.4 Sedimentation Technique

Patel et al (2007) concluded that raw bentonite can be purified by suspending less than 2% bentonite in deionized water. Sedimentation studies were carried out using Stoke's equation as shown below:

$$r^2 = \frac{9\eta h}{2\,(d_1 - d_2)\,gt}$$

Whereby r: radius of the given particle (assuming spherical, in micron)

h: height (cm) through which it falls in time t (s)

g: acceleration due to gravity

d_1, d_2: densities of solid and liquid respectively

η: viscosity of water

The results that indicate the synthesis and augmentation of bentonite should be conducted at lower concentration (<2%) are as shown in Appendix 3.

2.5 Drilling Fluid Evaluation

Drilling fluid must meet API 13[A] specifications for usage as an industrial drilling fluid. Previous works by Samsuri et. al. (2003) indicate that the most important of which are the Viscometer 600rpm Dial Reading and YP/PV (Yield Point/ Plastic Viscosity) Ratio along with Fluid Loss Control. The specifications as stated in API 13[A] for the 3 analysis benchmark are as shown below:

Requirement	API 13[A] Specification	Standard Bentonite
Viscometer Dial Reading at 600 rpm	30 (minimum)	32
YP/PV Ratio	3 (maximum)	1.2
Fluid Loss (cm^3)	15	14

Table 5: American Petroleum Institute (API) 13[A] Specifications for Water Based Drilling Fluid

2.6 Enhancement of Drilling Fluid Performance

Locally formulated drilling fluid must meet American Petroleum Institute (API) standards before they can be sold commercially. This section will look into work done in the industry to improve local drilling fluid performance and its' results.

2.6.1 Increase Shearing or Mixing Speed

Al-Homadhi(2007) concluded from his experiment that an increase in shearing speed from 6000 to 1500rpm increases the viscosity of the experimented drilling fluid containing bentonite mud by about 200% and a 35% reduction in filtration loss. This method has been proven to be highly effective but has some economical and equipment limitations. The first reason is due to the high energy requirements to run the equipment at high shearing speeds. Specialized shearing and mixing equipments would also need to be made available at the rig thus proving a disadvantage. The results of Al-Homadhi (2007) experiment on manipulation of mixing speed are as shown in Appendix 4.

2.6.2 Addition of Sodium Carboxymethyl Cellulose (CMC)

Sodium Carboxymethyl Cellulose (CMC) is a polyelectrolyte that increases the degree of polymerization and subsequently the viscosity of the drilling fluid (Irawan & Samsuri, 2007). CMC also reduces filtration loss at temperatures below 250°F and salts concentration below 50000ppm due to the long chain molecules. It has been observed from findings that the addition of CMC at a concentration of 6mg/L increases bentonite clay sample viscosity twofold. Even at a much lower concentration of 1mg/L, a sharp decrease in filtration loss from 50ml to 21ml was noted (Al-Homadhi, 2007). The results of Al-Homadhi (2007) experiment on addition of CMC are as shown in Appendix 5.

2.6.3 Addition of Polyanionic Cellulose Polymer (Drispac)

Al-Homadhi (2007) observed that Polyanionic Cellulose Polymer (Drispac) improves viscosity, reduces water and filtration loss at high salt concentration and down-hole temperature. This is due to the content of Drispac which is made up of long chain polymer of high molecular weight. From the authors' research, clay sample viscosity and water filtration loss must meet API specifications before being approved for use.

The results of Al-Homadhi (2007) experiment on the addition of Drispac are as shown in Appendix 6.

2.6.4 Addition of Sodium Sources

Addition of solutions that contain sodium ions increases clay dispersion and results in higher viscosity as a consequence of base exchange between calcium based clays and the sodium hydroxide solution (Al-Homadhi, 2007). However, the author discourages the use of NaOH if it increases the pH level to a higher degree than the suggested level (pH 9) for it to meet viscosity specifications as shown in the author's experiment. The results of Al-Homadhi (2007) experiment on addition of NaOH are as shown in Appendix 7.

Samsuri and Leyong (2002) stated that the sodium treatment was done under wet conditions. The additive is mixed with fresh water to form a sodium ion solution and blended with clay sample to form a clay solution and left for 2 days to ensure that the ion exchange can react effectively. However, the authors noted that improvements proved impossible if there is a lack of montmorillonite mineral of the clay sample thus making the addition of polymer useless.

CHAPTER 3

METHODOLOGY/ PROJECT WORK

The methodology and project work chapter of this report will first cover the activities that have been and will be conducted to fulfill the objectives of this report. A list of required equipments will also be attached along with the Gantt Chart of both Final Year Project 1 and 2.

3.1 Project Activities

This chapter describes the sequence and procedures of tests, experiments and enhancements that will be conducted upon the clay samples and subsequently the drilling fluid that will be formulated with the intention of ensuring that the drilling fluid fulfills the American Petroleum Institute (API) specifications. Figure 3 shows a flow sheet for the activities that will be carried out throughout the entire project for the formulation of drilling mud.

The first phase of this project was to carry out research into drilling fluid and more specifically, water based mud and the properties of bentonite clay as a whole. The functions of drilling mud and the factors required in the selection of drilling fluid acted as an introduction into the drilling fluid topic. Journal papers and current advancement in the drilling fluid industry were also looked into. Physical and chemical properties determination techniques (XRD, XRF and CEC) were also decided while methods for the purification and synthesis of bentonite were determined. An overall view into the current progress and research of this topic is available at the Literature Review.

In this study, three separate bulk samples of clay were obtained from a location in Grik. The next phase was the sample preparation process to ensure that the samples can be utilized efficiently. This will require the bentonite samples to be placed within an oven at 105°C for 1 day after obtaining the sample from the field to dry out the sample. Subsequently, the clay samples would be crushed with a mortar and pestle. This was followed by further sieving with a filter size of 63μm in size to remove any non-clay particles such as sand and stones that will affect the performance of the clay.

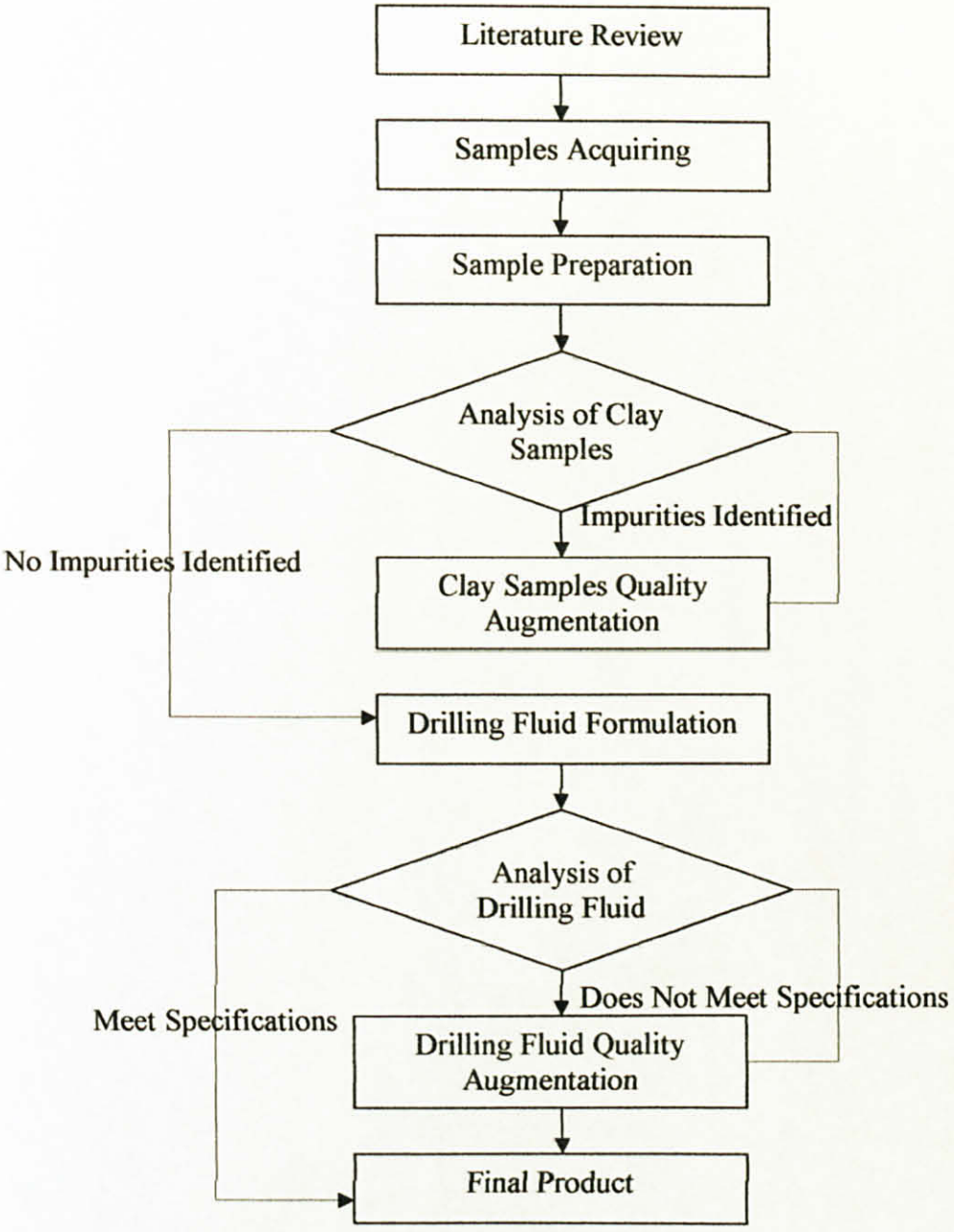

Figure 3: Flow Sheet for Expected Activities

From the prepared samples, we will be able to identify the samples we have at hand. The following are the tests that have been conducted and the justifications to performing these experiments if required:-

1. X-Ray Fluorescence
    - Used for elemental and chemical analysis
2. X-Ray Diffraction
    - Reveals information about the crystallographic structure, chemical composition, and physical properties of materials and thin films
3. Atterberg's Limit
    - Indicates the water absorption ability and indirectly the montmorillonite content.

From the identification of mineralogy, physical and chemical properties of the clay sample, we will look into impurities extraction and treatment process to enhance the qualities of the samples. The treatments available for augmentation of bentonite quality are:-

- Wet Treatment
- Electrolysis Treatment
- Oxalic acid solution treatment
- Sedimentation Technique utilizing Stoke's Law

The decision to proceed with the treatment will depend upon the completed analysis of the physical and chemical properties of the raw clay samples. The treatment of the clay samples will depend on the impurities present and the inadequacies as compared to standard Wyoming bentonite. Subsequently, the treated samples will be re-identified to acquire the efficiency and effectiveness of each treatment process.

Upon the augmentation of clay samples, the samples will be formulated as drilling fluid and analyzed for suitability. API specifications 13[A] will be used as a reference benchmark to decide upon the suitability of the formulated drilling fluid for industrial use.

The three main analyzed properties of water based drilling fluid that will be formulated are Viscosity (Viscometer 600rpm Dial Reading), Yield Point/ Plastic Viscosity (YP/PV) Ratio and Fluid Loss Control.

The performance of the formulated samples can be enhanced through several procedures. These procedures are utilized within the industry and by recent academic works. These procedures are:

- Increasing shearing or mixing speed
- Addition of Sodium Carboxymethyl Cellulose (CMC)
- Addition of Polyanionic Cellulose Polymer (Drispac)
- Addition of Sodium Hydroxide (NaOH)

3.2 Equipments

Listed below are the equipments/apparatus required segregated by where these items are utilized:

3.2.1 Bentonite Quality Evaluation

Test	Equipments Required
X-Ray Fluorescence	Bruker S4 Pioneer XRF Unit
X-Ray Diffraction	Bruker D8 Advance XRD Unit
Atterberg's Limits	Oven, Electronic Balance, Moisture Content Tins, Spatula, Cone Penetrometer, Timer

Table 6: Equipments required for the Analysis of Clay Samples

3.2.2 Bentonite Augmentation

Process	Equipments/ Chemicals Required
Wet Treatment	Mixing Container, Sodium Carbonate (Soda Ash)
Electrolysis Treatment	DC Power Supply, Aluminum Cathode & Anode, Sodium Carbonate
Oxalic Acid Treatment	Heating Unit, Oxalic Acid
Sedimentation Technique	Timer, Mixing Container

Table 7: Equipments required for the Augmentation of Clay Samples

3.2.3 Drilling Fluid Enhancement

Technique	Equipments/ Chemical Required
Increasing Shearing or Mixing Speed	High Shear Mixing Machine
Addition of Sodium Carboxymethyl Cellulose (CMC)	Mixing Tank, CMC Solution, Heater
Addition of Polyanionic Cellulose Polymer (Drispac)	Mixing Tank, Polyanionic Cellulose Polymer Solution
Addition of Sodium Hydroxide (NaOH)	Mixing Tank, Sodium Hydroxide Solution

Table 8: Equipments required for the Enhancement of Drilling Fluid

3.3 Gantt Chart

The Gantt Chart for Final Year Project 1 is as shown below.

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■		EMERGENCY BREAK							MID-SEMESTER BREAK				
2	Preliminary Research Work		■		■										
3	Project Work					■	■	■	■	■					
—	Identification of Composition of Local Clay					O	O	O							
—	Purification Process of Local Clay								O	O					
4	Lab Workshop						O								
5	Submission of Progess Report (I & II)							O							
6	HSE Workshop								O						
7	Referencing Workshop									O					
8	Project Work (II)											■	■	■	
—	Identification of Composition of Purified Local Clay											O	O	O	
9	Interim Report Submission												O		
10	Oral Presentation														O

Table 9: Gantt Chart for Final Year Project 1

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Analysis of Clay Samples	■						MID-SEMESTER BREAK							
2	Research At Jabatan Mineral & Geosains Perak		■												
3	Drilling Fluid Formulation			■											
4	Analysis of Drilling Fluid			■	■	■									
5	Submission For Progress Report						O								
6	Drilling Fluid Quality Augmentation								■	■					
-	Addition of Sodium Hydroxide								■	■					
7	Analysis of Treated Drilling Fluid								■	■					
8	Poster Exhibition											O			
9	Submission of Dissertation (Soft Bound)												O		
10	Oral Presentation														O
11	Submission of Dissertation (Hard Bound)														O

Table 10: Gantt Chart for Final Year Project 2

CHAPTER 4

RESULTS

The results that are included within this report are the plasticity limit, liquid limit, plasticity index, X-Ray Fluorescence, X-Ray Diffraction and formulated untreated and treated drilling fluid characteristics.

4.1 Plastic Limit

Sample Area	A		B		C	
Container No	A1	A2	B1	B2	C1	C2
Mass of Wet Soil + Container (g)	29.73	29.58	28.50	26.49	27.09	23.60
Mass of Dry Soil + Container (g)	27.19	27.60	26.90	25.30	25.91	22.60
Mass of Container (g)	18.60	20.90	20.50	20.53	21.06	18.50
Mass of Moisture (g)	2.54	1.98	1.60	1.19	1.18	1.00
Mass of Dry Soil (g)	8.59	6.70	6.40	4.77	4.85	4.10
Moisture Content, W (%)	29.57	29.55	25.00	24.95	24.33	24.39
Average Moisture Content	29.56		24.97		24.36	

Table 11: Plastic Limit of Clay Samples from Grik, Perak

4.2 Liquid Limit

Sample A

Container No	A1	A2	A3	A4	A5	A6
Penetration (mm)	9.30	13.50	17.50	20.20	22.40	26.00
Mass of Wet Soil + Container (g)	22.55	29.81	31.02	26.03	28.17	29.82
Mass of Dry Soil + Container (g)	21.50	27.40	28.10	24.50	25.90	26.30
Mass of Container (g)	18.63	21.11	20.51	20.54	20.83	18.59
Mass of Moisture (g)	1.05	2.41	2.92	1.53	2.27	3.52
Mass of Dry Soil (g)	2.87	6.29	7.59	3.96	5.07	7.71
Moisture Content, W (%)	36.59	38.31	38.47	38.64	44.77	45.65

Table 12: Liquid Limit of Clay Samples (Sample A) from Grik, Perak

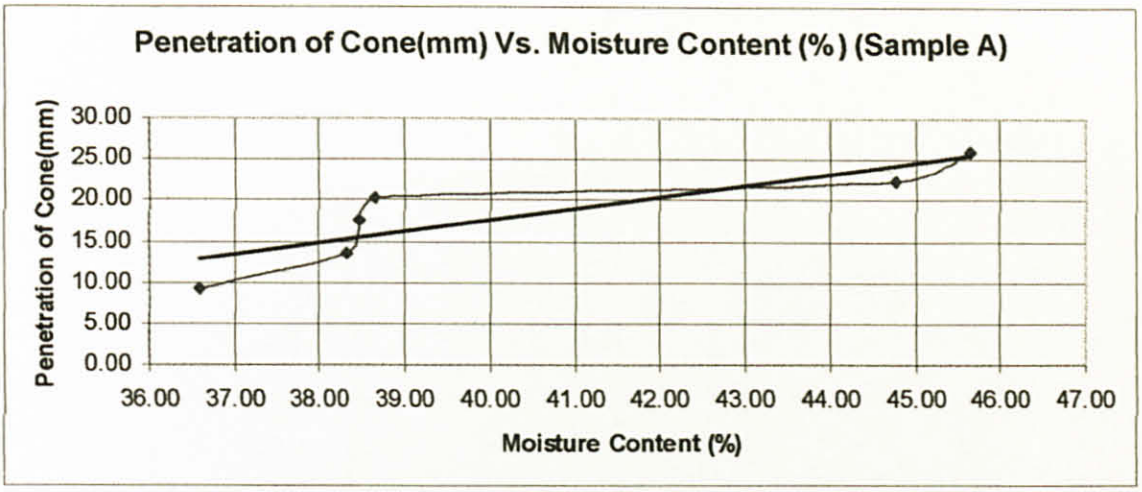

Figure 4: Penetration of Cone (mm) Vs. Moisture Content (%) of Clay Sample (Sample A) from Grik, Perak

Liquid Limit = Moisture Content at Penetration of Cone (20mm) obtained from best fit straight line = 41.7%

Sample B

Container No	A1	A2	A3	A4	A5	A6
Penetration (mm)	8.30	11.70	16.90	21.70	26.70	30.50
Mass of Wet Soil + Container (g)	22.84	31.07	27.08	29.12	27.61	30.74
Mass of Dry Soil + Container (g)	21.86	28.60	25.40	26.91	25.85	27.42
Mass of Container (g)	18.63	21.11	20.47	20.54	20.85	18.59
Mass of Moisture (g)	0.98	2.47	1.68	2.21	1.76	3.32
Mass of Dry Soil (g)	3.23	7.49	4.93	6.37	5.00	8.83
Moisture Content, W (%)	30.34	32.98	34.08	34.69	35.20	37.60

Table 13: Liquid Limit of Clay Samples (Sample B) from Grik, Perak

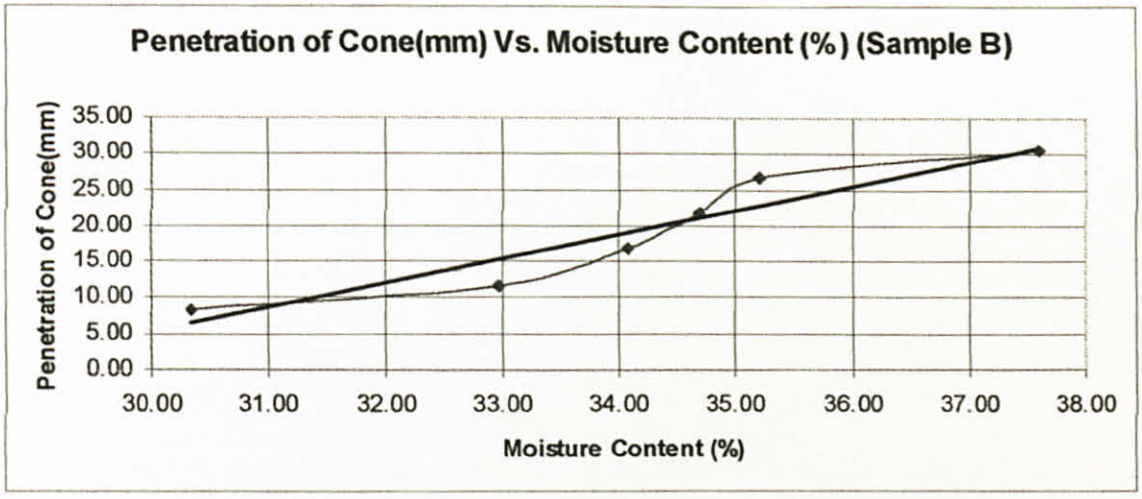

Figure 5: Penetration of Cone (mm) Vs. Moisture Content (%) of Clay Sample (Sample B) from Grik, Perak

Liquid Limit = Moisture Content at Penetration of Cone (20mm) obtained from best fit straight line = 34.3%

4.3 Plasticity Index

Sample A = Liquid Limit-Plastic Limit
= 41.7 - 29.56
= 12.14%

Sample B = Liquid Limit-Plastic Limit
= 34.3 - 24.97
= 9.33%

4.4 X-Ray Fluorescence (XRF)

Indicated below are the results for the three separate samples taken from Grik, Perak.

4.4.1 Grik A

Elements	Percentage (%)
O	50.0000
Mg	0.7410
Al	10.2500
Si	33.9400
P	0.3540
K	3.2660
Ca	0.1080
Ti	0.1260
Mn	0.0155
Fe	1.1500
Rb	0.0139
Zr	0.0174
Ar	1.2250
Total	100.0

Oxide Composition	Percentage (%)
MgO	1.2300
AL_2O_3	19.3600
SiO_2	72.6000
P_2O_5	0.8120
K_2O	3.9350
CaO	0.1520
TiO_2	0.2100
MnO	0.0201
Fe_2O_3	1.6450
Rb_2O	0.0152
ZrO_2	0.0235
Total	100.0

Table 14: Elemental composition and oxide composition percentage of Sample A

4.4.2 Grik B

Elements	Percentage (%)
O	50.0000
Mg	0.8460
Al	9.4850
Si	34.2000
P	0.3240
K	3.4980
Ca	0.0931
Ti	0.1220
Mn	0.0175
Fe	1.5120
Rb	0.0138
Zr	0.0167
Ar	1.1590
Total	100.0

Oxide Composition	Percentage (%)
MgO	1.4000
AL_2O_3	17.9200
SiO_2	73.1600
P_2O_5	0.7420
K_2O	4.2140
CaO	0.1300
TiO_2	0.2040
MnO	0.0226
Fe_2O_3	2.1620
Rb_2O	0.0151
ZrO_2	0.0226
Total	100.0

Table 15: Elemental composition and oxide composition percentage of Sample B

4.4.3 Grik C

Elements	Percentage (%)
O	49.0000
Mg	1.1300
Al	10.7100
Si	32.0000
P	0.3330
K	5.0560
Ca	0.1020
Ti	0.1450
Fe	1.5120
Zn	0.0028
Rb	0.0191
Zr	0.0203
Ar	1.1690
Total	100.0

Oxide Composition	Percentage (%)
MgO	1.8700
AL_2O_3	20.2400
SiO_2	68.4500
P_2O_5	0.7640
K_2O	6.0900
CaO	0.1430
TiO_2	0.2420
Fe_2O_3	2.1510
ZnO	0.0035
Rb_2O	0.0209
ZrO_2	0.0274
Total	100.0

Table 16: Elemental composition and oxide composition percentage of Sample C

4.5 X-Ray Diffraction (XRD)

4.5.1 Sample A

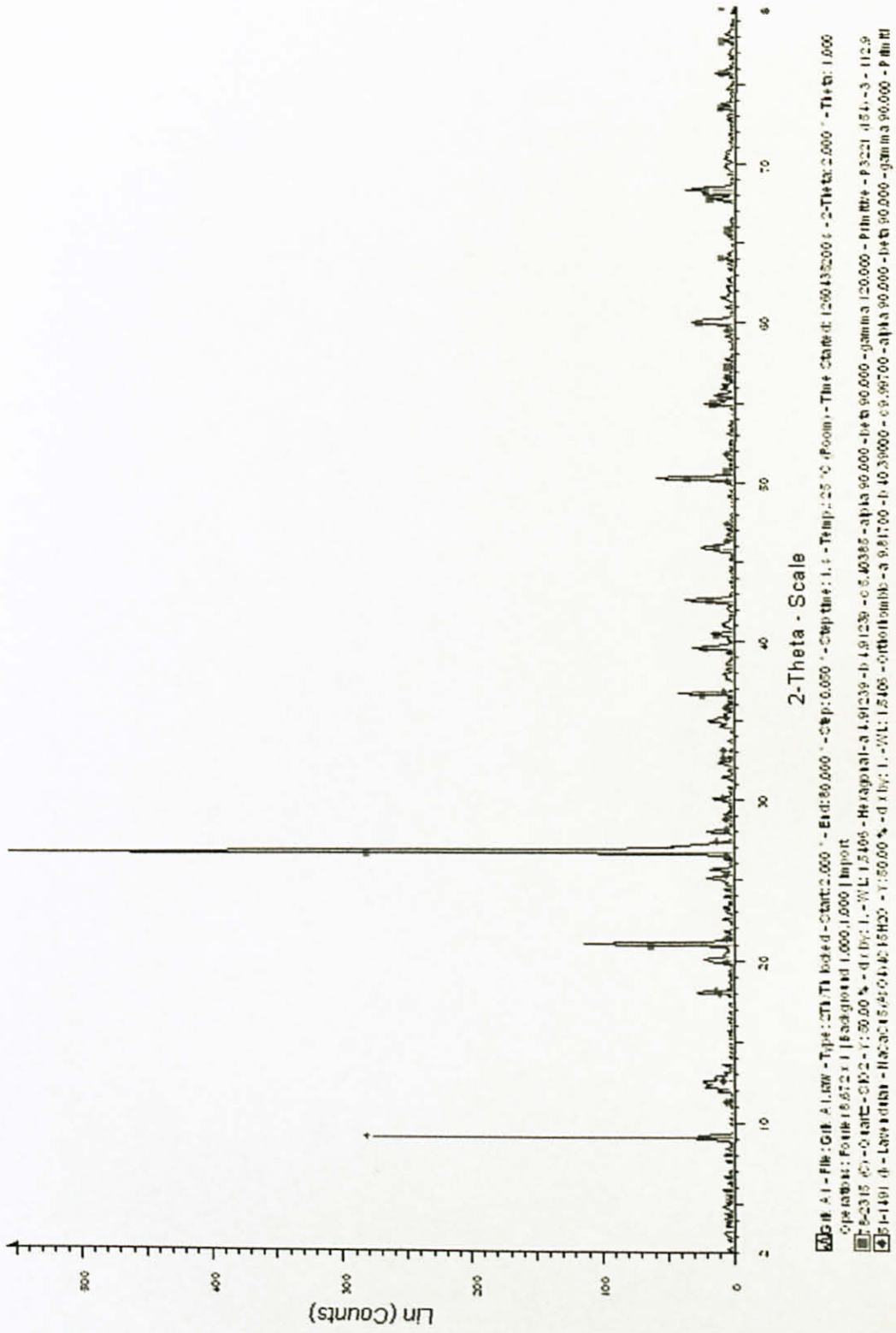

Figure 6: X-Ray Diffraction Graph for Sample A

4.5.2 Sample B

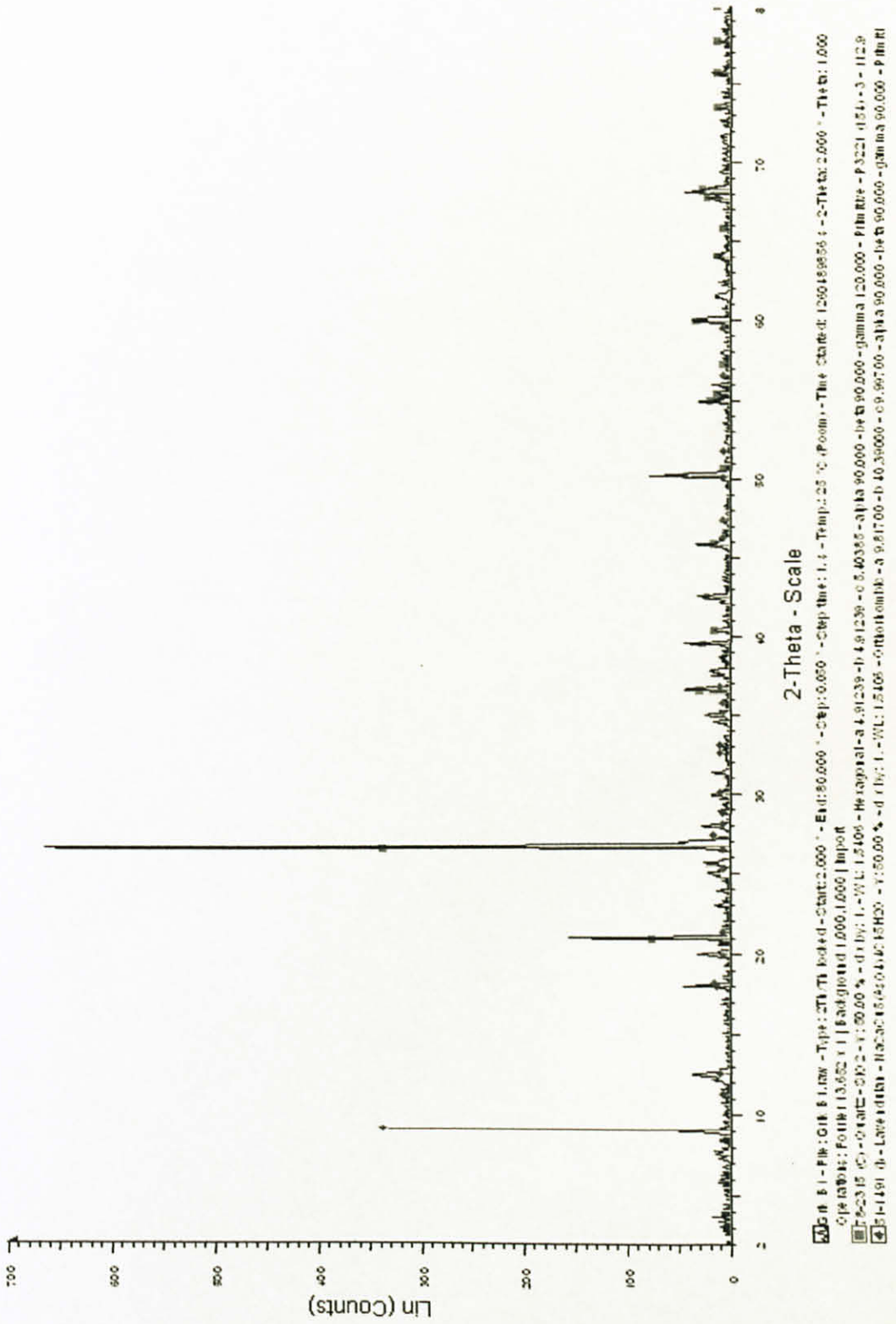

Figure 7: X-Ray Diffraction Graph for Sample B

4.5.3 Sample C

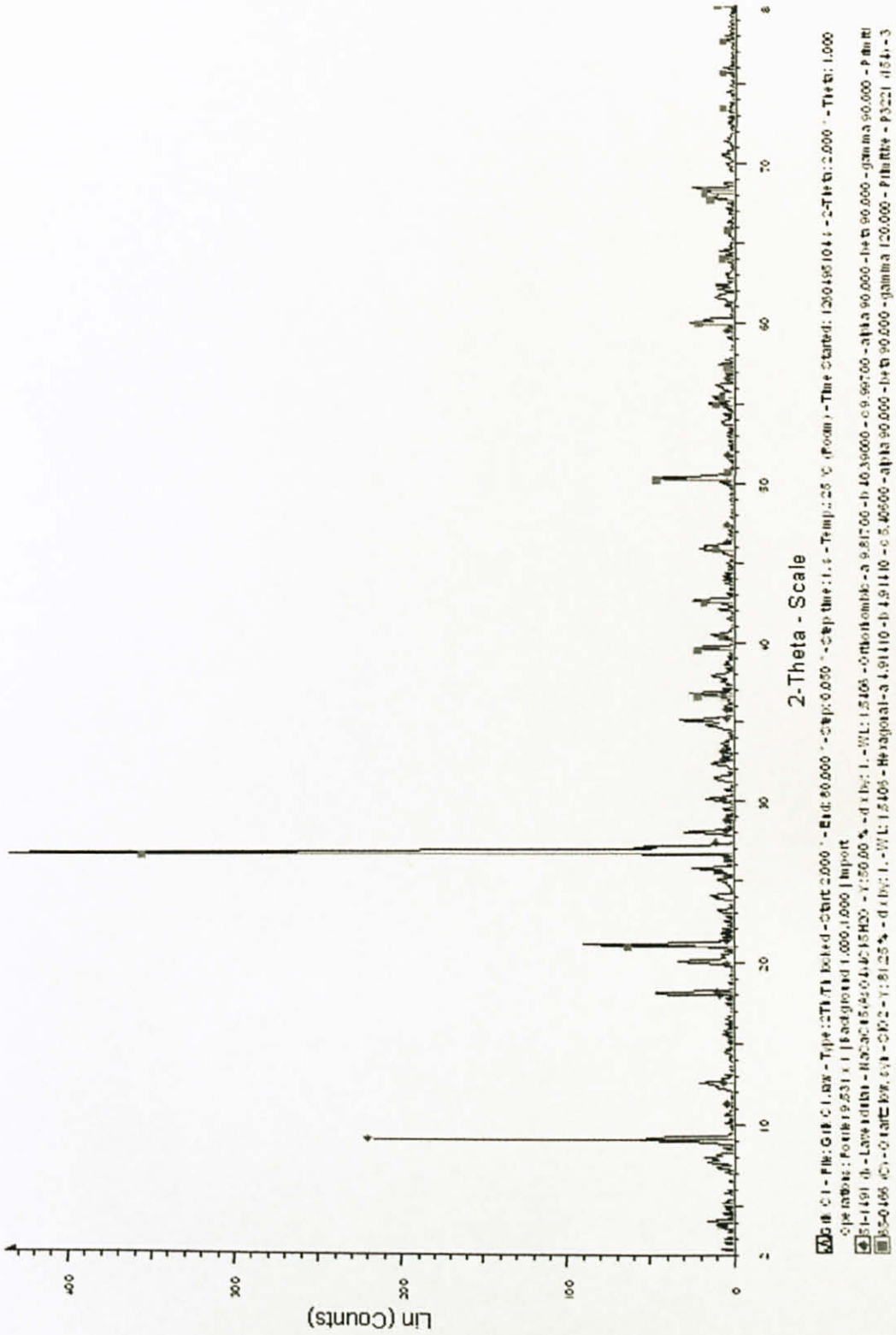

Figure 8: X-Ray Diffraction Graph for Sample C

4.6 Formulated Drilling Fluid

Indicated below are the results obtained from the untreated formulated drilling fluid:

4.6.1 Mud Weight

Sample	Mud Weight (Lbs/gal)
A	8.6
B	8.8
C	8.7
Avg	8.7

Table 17: Mud Weight of Untreated Formulated Drilling Fluid

4.6.2 Marsh Funnel Viscosity

Sample	Viscosity (Sec)
A	14.37
B	14.25
C	13.97

Table 18: Marsh Funnel Viscosity of Untreated Formulated Drilling Fluid

4.6.3 *Mud Rheology Test*

Sample	Viscosity				
	ϕ600	ϕ300	M_p	μ_a	Y_p
A	4	3	1	2	2
B	5	4	1	2.5	3
C	4	3	1	2	2
Avg	4.3	3.3	1.0	2.2	2.3

Table 19: Mud Rheology of Untreated Formulated Drilling Fluid

4.6.4 Gel Strength

Sample	Initial 10 sec. Gel	Final 10 min. Gel
1	3	2
2	3	2
3	3	2
Avg	3	2

Table 20: Gel Strength of Untreated Formulated Drilling Fluid

From the results shown, the treatment that will prove to be most suitable is Sodium Hydroxide Addition. The results are shown in the following section.

4.7 Treated Drilling Fluid

4.7.1 Marsh Funnel Viscosity

Sample (gm/L)	Sample A Viscosity (Sec)	Sample B Viscosity (Sec)	Sample C Viscosity (Sec)
0	14.37	14.25	13.97
1	14.06	14.16	14.26
2	14.28	13.97	14.32
3	14.13	14.37	14.02
4	14.24	14.29	14.11
5	13.93	14.07	14.17
6	14.33	14.03	14.22

Table 21: Marsh Funnel Viscosity of Treated Drilling Fluid

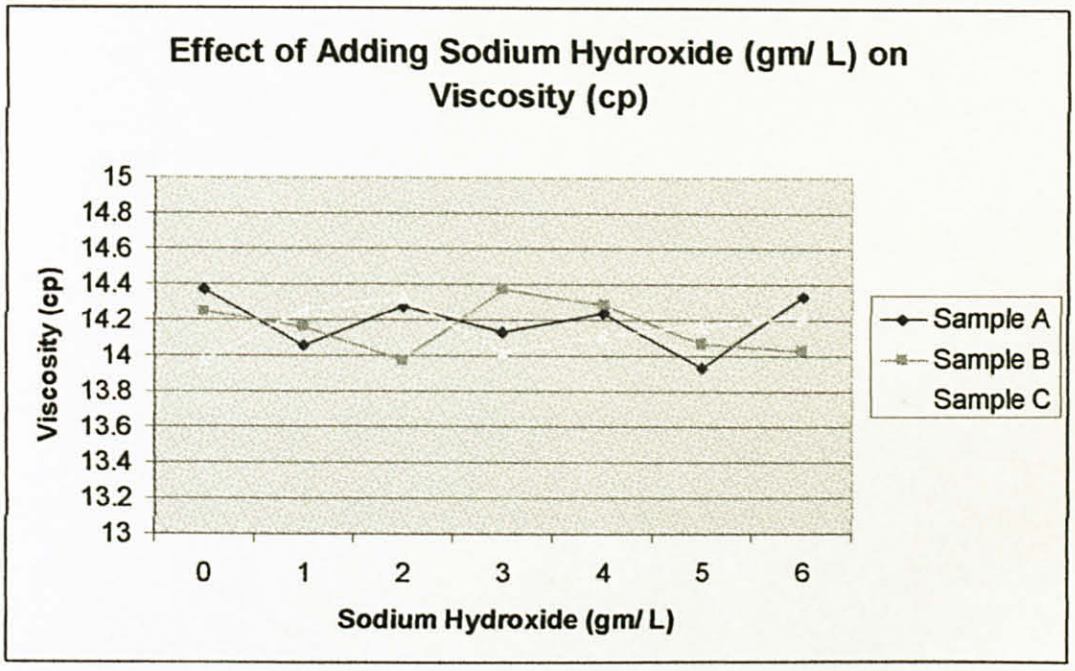

Figure 9: Effect of Adding Sodium Hydroxide (gm/ L) on Viscosity (Sec)

4.7.2 Mud Rheology Test

Sample (gm/L)	Sample A Y_P/PV	Sample B Y_P/PV	Sample C Y_P/PV
0	2	2	2
1	2	2	2
2	2	2	1
3	3	1	2
4	2	2	2
5	2	2	2
6	2	2	1

Table 22: Mud Rheology of Treated Drilling Fluid

CHAPTER 5

DISCUSSION

This section will discuss on the results of the experiments that have been performed in Final Year Project thus far.

5.1 Atterberg's Limit

From the results show in Section 4 of the report, Sample Area A and B have a plastic limit of 29.56% and 24.97% respectively. The liquid limit for Sample Area A and B on the other hand are 41.7 % and 34.3%. Thus, from the data acquired, the Plasticity Index for Sample Area A is 12.14% and 9.33%. Thus, from the British Standard (BS 1377: Part 2: 1990: 4.3/4.4* as per attached in Appendix 8), it is highly indicative that the samples are clay by nature with low plasticity. Both samples have much lower Plasticity Index as compared to reference Wyoming bentonite. Thus, the clay samples taken from Grik, Perak requires treatment before being approved for usage.

5.2 X-Ray Fluorescence

From the results indicated in Chapter 4 of this report and in comparison to the chemical analysis of tuffs from Grik done prior to this as stated in the Literature Review, it is highly indicative that the clay sample obtained originates from weathered clay that is rhyolitic and rhyodacitic crystal tuffs by nature. This is due to the almost similar chemical composition of the obtained samples to that of the 1st sample of the analysis of tuffs from Grik. The specimen is a potassium-rich tuff containing abundant potassic feldspar and is highly probable to be kaolinite or illite. The major impact of this result is that the sample might not prove to be suitable for usage of drilling mud as both these clay types have low shrink-swell capacities and a low cation-exchange capacity.

5.3 X-Ray Diffraction

From the X-Ray Diffraction results shown above, and in comparison to the XRD of analysis of illite, kaolinite, and quartz available in Appendix 9. It is highly indicative that the sample comprises a large portion of illite and quartz due to the similar peaks at 2-theta-scale. This further reinforces the data from the XRF analysis and the literature review stating that the material is weathered rhyolitic tuff that is illite clay by nature and thus proves to be unsuitable as drilling fluid.

5.4 Formulated Drilling Fluid

The formulated drilling fluid does not meet American Petroleum Institute Specifications for 2 benchmarks. The viscometer dial reading of 4.3 average is far below the minimum requirement of 30 as stated in the API 13[A]. This indicates that the fluid has very little resistance to flow and cannot be used in the industry. The Yield Point/ Plastic Viscosity at 2.3 fulfills the requirement of a maximum specification of 3. The yield point reflects the ability of the mud to carry drilled cuttings out of the hole as it measures the electro-chemical/ attractive forces in the mud under dynamic conditions. The gel strength of initial 10-sec and initial 10-min is also low at 3 and 2 respectively. This low level of gel strength indicates that very little gelation will occur after circulation has ceased and is caused by insufficient amounts of montmorillonite content in the sample. It is thus unsuitable to be used as a drilling fluid as it will allow cuttings to sink at the bottom.

5.5 Treated Drilling Fluid

From the Sodium Hydroxide Treatment of the samples, there was no increase in the rheological properties of the treated samples. This lack of increment in rheological properties is most likely caused by the absence of ion exchange between the potassium ion and sodium ion and the lack of montmorillonite mineral in the clay sample thus making the addition of polymer useless. Thus, the samples ultimately does not meet American Petroleum Institute 13[A] specifications for Viscosity and Yield Point/ Plastic Viscosity requirements. From physical indication, it can be seen that there are no gelling effects for both the pre and post treated drilling fluid. This could be caused by the nature of the clay which is illite (held together its clay sheets with potassium ions) and high quartz content that subsequently causes lower swelling and absorbency capacities. With the large difference between the current and

expected value of the drilling fluid, it would be uneconomical to add polymer extenders to improve the rheological properties of the sample. Thus, it would be best to consider the clay samples from Grik to not be functional and useful as drilling fluid.

CHAPTER 6

RECOMMENDATION

6.1 Development of Local Water Based Drilling Fluid Suitable for Reactive Shale.

Patel, Stamatakis, Young & Friedheim (2007) stated that drilling through reactive shale formations requires the usage of Non-Aqueous Drilling Fluid (NADF) as water sensitive shale will take up water from drilling fluid if water based drilling fluid is used. This results in rapid swelling or dispersion of shale depending upon the chemical composition of the shale and will finally result in stuck pipe or borehole wash out. However, NADF has certain disadvantages such as high cost, environmental pollution, HSE issues (disposal and health hazards). Thus, it is suggested that a continuation of Local Material for Drilling Fluid Formulation can take into consideration water based drilling fluid that can be used in reactive shale formations. Patel et al. (2007) stated that highly lipophilic amines have been proven as excellent shale inhibitors. Thus, research can be carried out to increase the effectiveness and flexibility of our local drilling fluid with integration from this project and outside sources.

6.2 Development of Sample for Usage as Liner Material

Liners are conventionally used in waste disposal facilities to prevent the contamination of local surroundings from contaminants. Sivapullaiah and Lakshmikantha (2005) stated that fine-grained soils such as clay are typically used for water-retaining structures and have also been found to be useful as a base and cover sealing sample due to its' low permeability and diffusivity, long-term stability, proper swelling and shrinking characteristics and also constructability. The researchers improved the geotechnical properties of illite by incorporating bentonite alongside lime that enables the illite-bentonite sample to be used commercially as

liner material. Thus, the author suggests that the clay samples from Grik, Perak should be researched and developed further so that it could be used as liner material.

6.3 Development of Sample as Building Materials for Disaster Relief Structures

Chai (2010) concluded from his research that clay samples from Grik, Perak could be used extensively as the main building material to provide physical protection and warmth to its occupants during natural catastrophes. The large Silicon Dioxide (SiO_2) content enables the sample to be used as a cheap source to form a brick-like layer on the exterior of the Disaster Relief Structures. The processed clay samples with the layering of crystallized silica will enable the structure to be waterproof on its' outer walls thus preventing the deterioration of the structures especially in tropical regions with its' torrential rainfall. Thus, it is highly hopeful that further research and development of the clay samples can be done within this specific field.

CHAPTER 7

CONCLUSION

The ever increasing consumption of imported Wyoming bentonite clay in drilling operations necessitates the search of a low cost local alternative replacement for reduction in cost of oilwell drilling and completions activities. The area of Grik and more specifically where the sample was obtained was studied thoroughly with information obtained from Jabatan Mineral & Geosains Perak. Multiple researches around the world have also been done to identify, synthesize and improve on bentonite clay and drilling fluid quality. The clay sample that will be utilized to formulate drilling fluid was obtained from Grik, Perak and Atterberg's Limit Test indicates that the clay samples are low plasticity clay by nature. X-Ray Fluorescence and X-Ray Diffraction techniques have indicated that the clay sample obtained comprises mostly of illite and quartz. Thus, the sample has been proven to not be Wyoming Bentonite by nature and has been deemed to be unsuitable for usage as drilling fluid. The drilling fluid rheology test confirms the data from the XRF and XRD analysis. The addition of Sodium Hydroxide (NaOH) proved to not be able to augment and synthesize the clay samples obtained from Grik and formulate the drilling fluid as per requirement from the American Petroleum Institute (API).

CHAPTER 8

ECONOMIC CONSIDERATIONS

This section of the report will detail the economic aspects of the project. The cost spent for this project will first be detailed before we move on to the business consideration and other elements that are relevant to the economic value of the project.

As a whole, this particular project was conducted with minimal cost spent as the analysis, augmentation and formulation procedures carried out were conducted within the university. The Atterberg's Limit Test was conducted in the Geotechnical Engineering Laboratory of Civil Engineering department whilst the X-Ray Diffraction and X-Ray Fluorescence were carried out in the Materials Laboratory of the Mechanical Engineering Department. As for the augmentation and formulation of the drilling fluid itself, it was conducted in the Geoscience and Petroleum Engineering laboratory. However, it should also be noted that if the analytical test conducted within the report were conducted by technical specialists in the government of private sector, the cost would be as stated below:

Test	Fees (RM) (per sample)	Minimum Weight Required (kg)
Atterberg's Limit	125	2
XRF (Oxide Composition)	70 (Per Constituent)/ 770 (Total Cost)	0.1
XRF (Elemental	10 (Per Constituent)/	0.1

XRF (Elemental Composition)	10 (Per Constituent)/ 130 (Total Cost)	0.1
XRD	120 (Total Cost)	0.1

Table 23: Financial Cost Outlay for Analytical Test (Taken from Jabatan Mineral & Geosains Perak, 2010)

With the advanced equipment available within the university, the author was able to conduct the experiments and formulate the drilling fluid while ensuring minimal financial outlay.

As for the business elements of the project, the formulated drilling fluid proved to be unsuitable for industrial usage as it was below industrial specifications (API 13[A]) and addition of additives would be uneconomic as vast quantities would be required. However, the clay material utilized for this project has shown to be suitable for usage as building material for Disaster-Relief Structures (Chai, 2010) or as liner material. The area where the sample was obtained has been estimated to be about 60 square miles with a clay volume of 466,197,860m^3 (Clay layer estimated to be 3 meters in depth) and easily extractable as it is located on the surface (Jones, 1970). Thus, it would be economically and financially beneficial to exploit the said area for utilization.

As a conclusion, the project was conducted with minimal financial outlay as the required equipments were readily available within the university. The clay samples, although unsuitable for usage as drilling fluid, can be economically exploited for usage as building or liner material instead.

CHAPTER 9

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CHAPTER 10

APPENDICES

9.1 Appendix 1

Mineral	Standard Bentonite	Unheated			Wet treatment			Electrolysis treatment		
		SA5-1	SA5-4	M4	SA5-1	SA5-4	M4	SA5-1	SA5-4	M4
Montmorillonite	****	***	***	**	***	***	**	***	***	*
Quartz	*	*	*	***	*	*	***	*	*	***
Kaolinite	*	*	*	tr	*	*	*	*	*	tr
illite	*	**	**	*	**	**	*	**	**	*
Others	Tr Feldspar	* feldspar	* feldspar	* feldspar	* feldspar	* feldspar	* feldspar	* feldspar	* feldspar	* feldspar

Note: ****: Dominant, ***: Major, **: Minor, *: Appreciable, tr: Trace

Table 24: Semi-quantitative analysis of untreated and treated Andrassy and Mansuli as compared to the standard bentonite.

Sample	Unheated			Wet treatment			Electrolysis treatment		
	Liquid limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquid limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquid limit (%)	Plastic Limit (%)	Plasticity Index (%)
Standard Bentonite	583.12	57.64	524.48	-	-	-	-	-	-
SA5-1	68.32	32.21	36.11	219.50	50.21	169.30	192.49	35.57	156.92
SA5-4	122.84	42.36	80.48	248.50	45.83	202.70	306.95	38.90	268.05
M4	79.69	29.79	49.90	65.80	30.66	35.20	66.53	34.81	51.34

Table 25: Comparison of the Atterberg Limit between Andrassy and Mansuli bentonite samples, and standard bentonite.

Sample	Untreated			Wet treatment			Electrolysis treatment		
	Moisture Content (%)	Moisture Adsorption (%)	Ignition Loss (%)	Moisture Content (%)	Moisture Adsorption (%)	Ignition Loss (%)	Moisture Content (%)	Moisture Adsorption (%)	Ignition Loss (%)
Standard Bentonite	4.88	30.31	8.53	-	-	-	-	-	-
SA5-1	9.39	11.91	10.32	5.63	17.25	10.03	8.71	17.03	11.23
SA5-4	9.49	21.53	11.31	7.91	21.58	11.03	10.29	20.22	10.29
M4	7.39	9.51	9.31	1.69	10.85	7.51	4.9	7.69	7.69

Table 26: MC, MA and IL values of untreated and treated Andrassy and Mansuli bentonite as compared to standard bentonite.

Sample	Untreated	Wet treatment	Electrolysis treatment
	CEC (meq/100 g)	CEC (meq/100 g)	CEC (meq/100 g)
Standard bentonite	79	-	-
SA5-1	42	53	52
SA5-4	54	66	66
M4	24	24	25

Table 27: CEC of untreated and treated bentonite as compared to standard bentonite

Sample	Untreated	Wet treatment	Electrolysis treatment
	Specific Surface (m^2/g)	Specific Surface (m^2/g)	Specific Surface (m^2/g)
Standard Bentonite	819.62	-	-
SA5-1	324.18	526.02	526.02
SA5-4	434.28	636.12	672.82
M4	151.69	204.29	140.68

Table 28: Specific surface of untreated and treated Andrassy and Mansuli bentonite as compared to standard bentonite

Chemical compound	Chemical composition (% weight)									
	Standard bentonite	Untreated			Wet treatment			Electrolysis treatment		
		SA5-1	SA5-4	M4	SA5-1	SA5-4	M4	SA5-1	SA5-4	M4
Fe	13.98	7.00	3.66	13.39	6.03	3.44	12.17	6.45	11.83	9.09
Na	4.13	0.73	0.39	1.62	2.39	6.28	5.10	4.20	4.99	3.85
Mg	5.15	1.51	2.00	2.60	3.12	2.63	3.74	2.47	3.44	2.72
Al	15.84	29.64	24.18	16.36	24.41	21.41	18.85	24.54	21.72	9.82
Si	57.58	57.91	60.72	60.25	60.86	61.33	53.18	58.25	49.46	67.17
K	0.51	0.82	2.84	4.02	0.96	1.53	5.61	1.25	2.96	4.29
Ca	1.88	1.71	4.95	0.70	1.51	3.05	0.36	2.09	3.65	1.31
Mn	0.94	0.68	1.26	1.05	0.72	0.33	1.01	0.74	2.01	1.76
Total	100.01	100.00	100.00	99.99	100.00	100.00	100.00	99.99	100.06	100.01

Table 29: Chemical composition of untreated and treated Andrassy and Mansuli bentonite as compared to standard bentonite

**Data obtained from Samsuri, A., SPE, Leyong, K.P., Abdullah, H., (2003). Potential of an Andrassy and Mansuli Bentonite as a Drilling Mud Material. SPE, 80494.*

9.2 Appendix 2

Bentonite Sample	CEC (meq/100g)			Specific Surface (m^2/g)		
	Original	Beneficiated	% of change	Original	Beneficiated	% of change
Reference Bentonite	80.00	-	-	660.37	-	-
SA5-1	30.00	65.00	54.00	160.11	540.00	70.35
SA5-3	39.50	60.00	34.00	282.20	340.00	17.00
SA5-4	27.00	72.00	64.00	338.40	640.00	47.13
SA5-7	41.00	68.00	40.00	253.92	400.00	36.52
M4	25.24	36.05	30.00	13.50	300.00	104.50

Table 30: CEC and specific surface area of beneficiated bentonite sample using oxalic acid treatment

**Data obtained from Irawan, S. & Samsuri, A. (2007). Drilling Mud Material Cost Saving through Utilization of Treated Malaysian Local Bentonite. Platform, 5(2), 13-20.*

9.3 Appendix 3

Sample	CEC (meq/100 g of clay)	CEC by CE method (meq/100 g of clay)	MMT content (% w/w)	Swelling volume (cc/ml)	Brightness index
B (raw)	64	–	–	16	54
B4 (4%)	67	88	76	16	55
B3 (3%)	72	93	77	17	55
B2 (2%)	80	97	82	21	57
B1 (1%)	91	104	87	24	60
B0.5 (0.5%)	91	104	87	24	60
A (raw)	61	–	–	21	53
A4 (4%)	62	83	74	21	53
A3 (3%)	77	91	84	21	53
A2 (2%)	81	95	85	25	56
A1 (1%)	88	102	86	29	58
A0.5 (0.5%)	88	102	86	29	58

Table 31: Cation Exchange Capacity (CEC) and montmorillonite (MMT) content, swelling volume and brightness indices of raw (A and B) and purified (B0.5,B1,B2,B3,B4 and A0.5,A1,A2,A3,A4) bentonite samples

**Data obtained from Patel, H.A., Somani, R.S., Bajaj, H.C., Jasra, R.V., (2007). Synthesis and Characterization of Organic Bentonite Using Gujarat and Rajasthan Clays. Current Science, 92(7), 1004-1009.*

9.4 Appendix 4

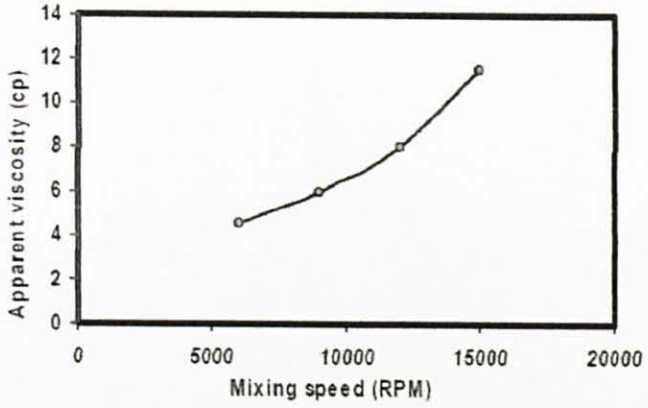

Figure 10: Effect of drilling mud mixing speed on Apparent Viscosity

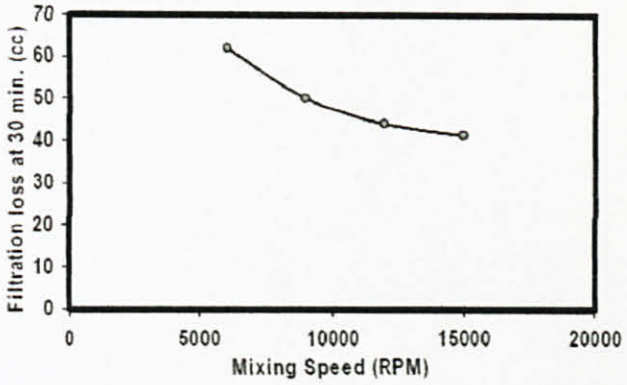

Figure 11: Effect of drilling mud mixing speed on Filtration Loss

** Data obtained from Al-Homadhi, E.S. (2007). Improving Local Bentonite Performance for Drilling Fluids Applications. SPE, 110951.*

9.5 Appendix 5

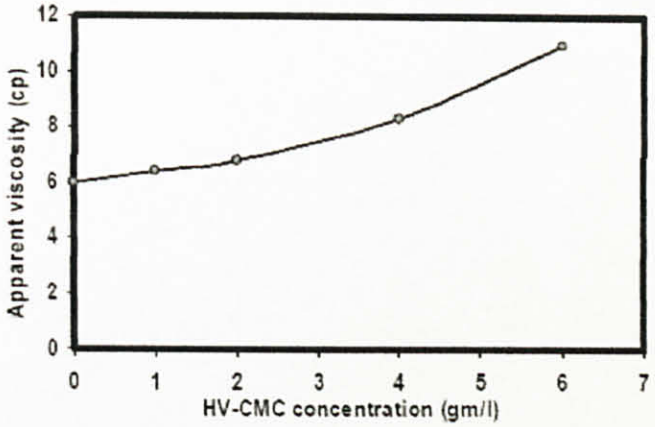

Figure 12: Effect of adding CMC on the viscosity of drilling mud

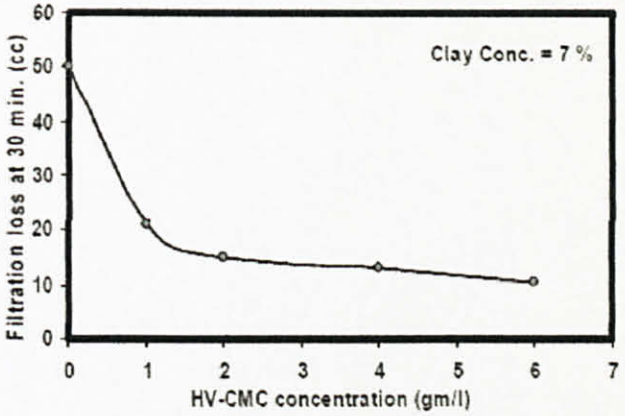

Figure 13: Effect of adding CMC on the Filtration Loss of drilling mud

** Data obtained from Al-Homadhi, E.S. (2007). Improving Local Bentonite Performance for Drilling Fluids Applications. SPE, 110951.*

9.6 Appendix 6

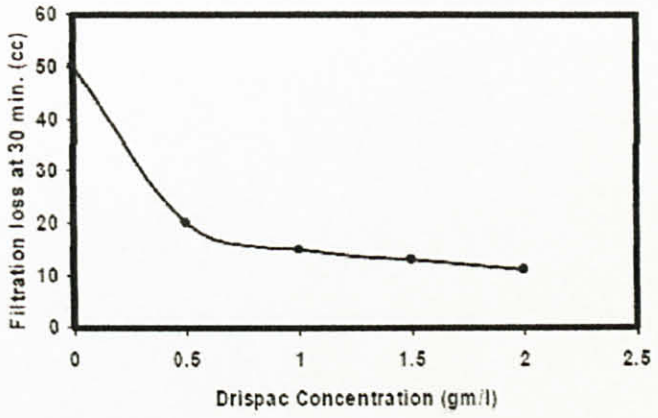

Figure 14: Effect of adding Drispac on the Filtration Loss of drilling mud

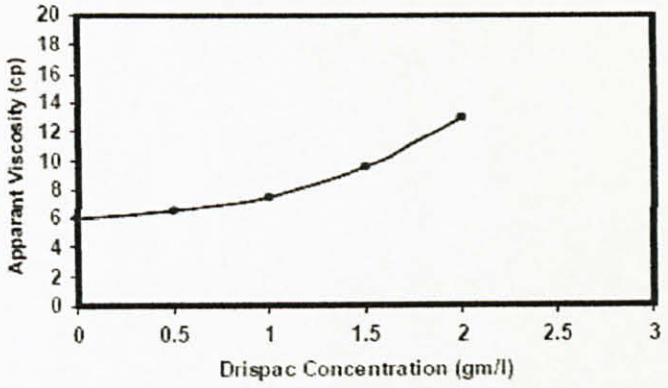

Figure 15: Effect of adding Drispac on the viscosity of drilling mud

** Data obtained from Al-Homadhi, E.S. (2007). Improving Local Bentonite Performance for Drilling Fluids Applications. SPE, 110951.*

9.7 Appendix 7

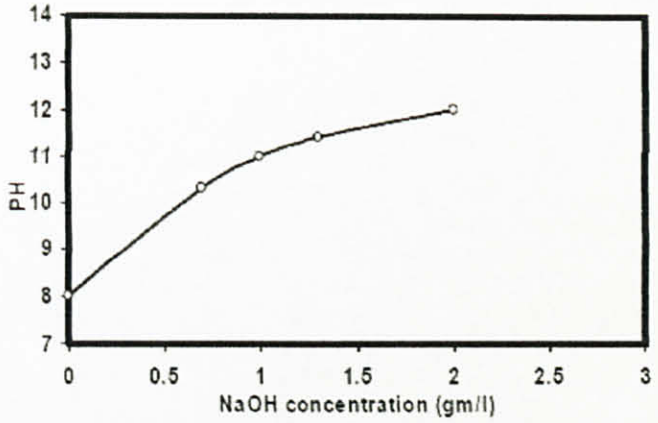

Figure 16: Effect of adding Caustic Soda on the pH of the drilling mud

** Data obtained from Al-Homadhi, E.S. (2007). Improving Local Bentonite Performance for Drilling Fluids Applications. SPE, 110951.*

9.8 Appendix 8

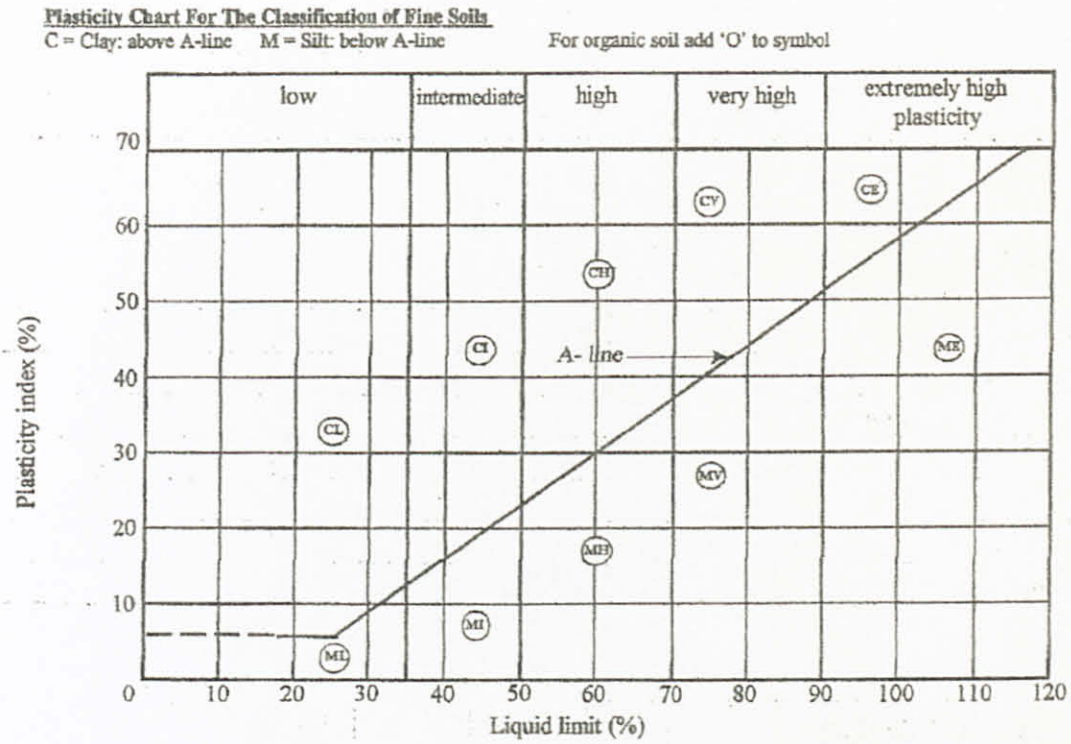

Figure 17: Plasticity Chart for the Classification of Fine Soils.

** Data obtained from British Standard (BS 1377: Part 2: 1990: 4.3/4.4*)*

9.9 Appendix 9

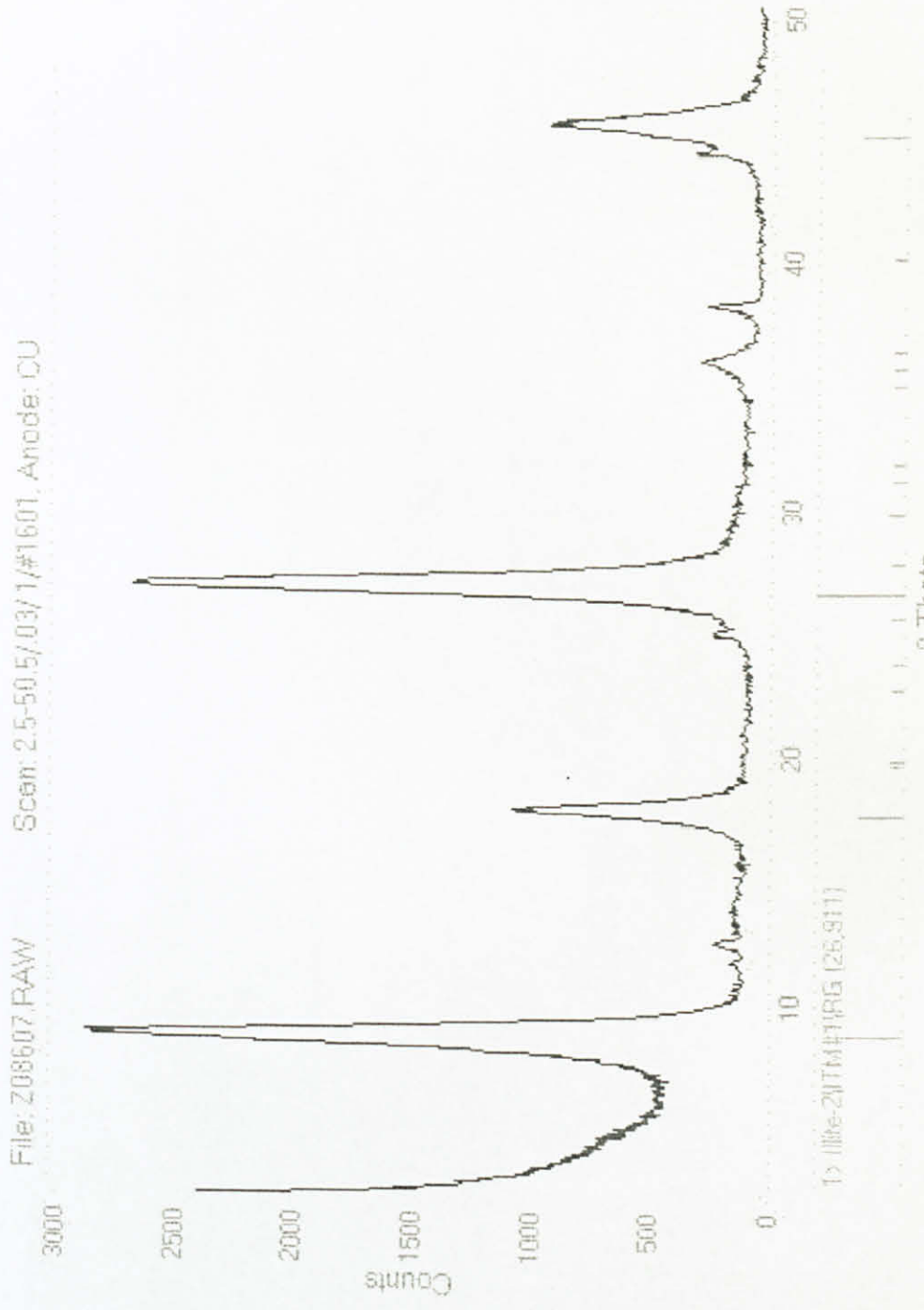

Figure 18: X-Ray Diffraction Analysis for Illite.

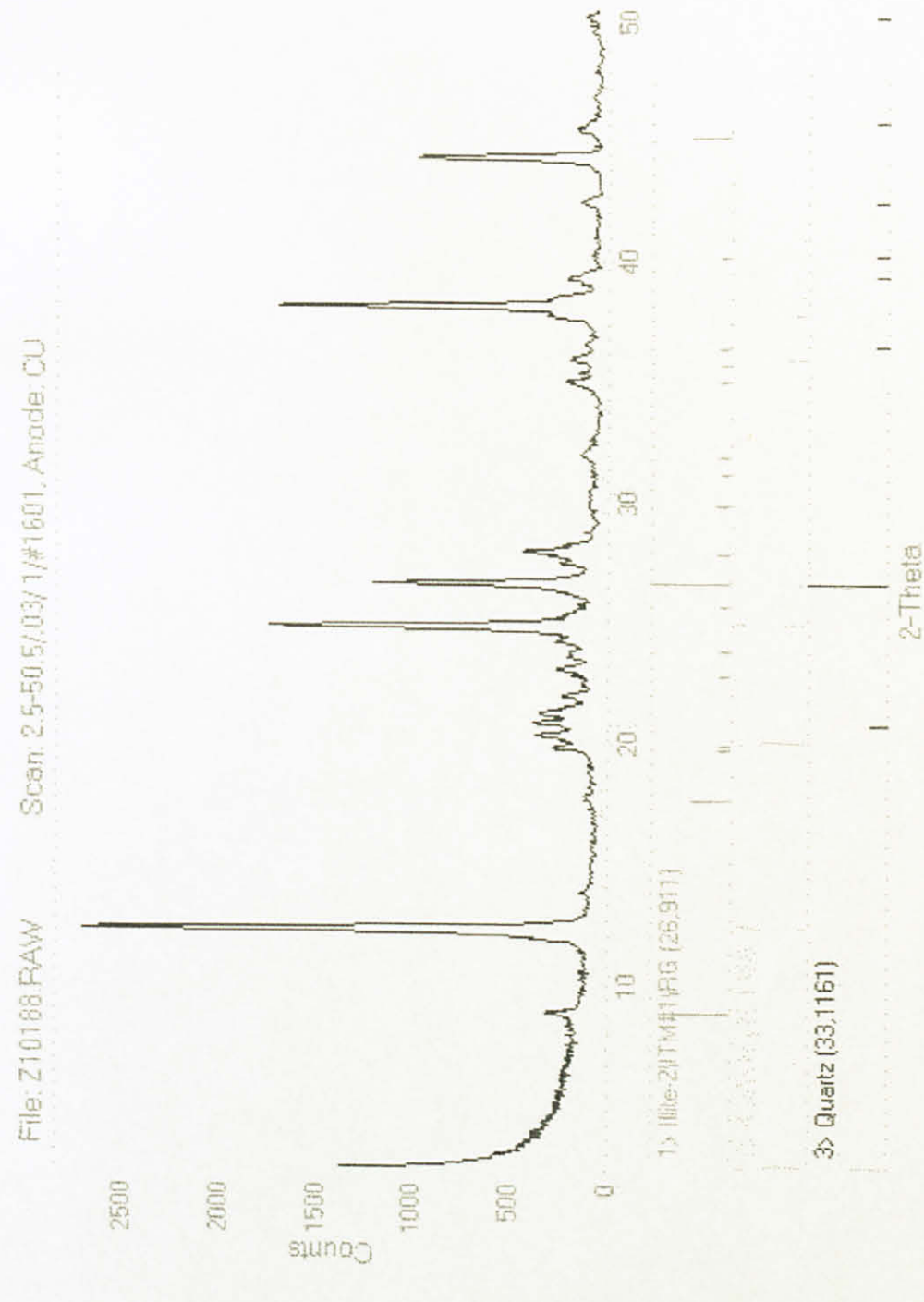

Figure 19: X-Ray Diffraction Analysis for Illite, Kaolinite and Quartz.

* *Data obtained from http://www.ktgeo.com/tEX.html*